

EXTRAOCULAR MUSCLES: VARIATION IN THEIR ANATOMY, LENGTH AND CROSS-SECTIONAL DIAMETER

Edward Ridyard.

Foundation Year 2 doctor, Oxford University Hospitals, Prescot, UK.

ABSTRACT

Background: The extraocular muscles (EOMs) bring about eye movement and studies exist which measure EOM length, cross-sectional diameter and volume. Knowledge of the normal values is crucial for determining when an EOM becomes pathological. The aim of this study was to dissect the orbit and measure the length and cross-sectional diameter of the EOMs.

Methods and Materials: Eighteen orbits from 9 formalin fixed cadavers (4 male, 5 female), age range 70-95, were dissected. The length of the EOM was measured with a digital caliper, the halfway point of the EOM found and the cross-sectional diameter measured. Length and cross-sectional diameter measurements from the left and right orbits were compared. The correlation between age and EOM length and age and EOM cross-sectional diameter was assessed. The association between gender and EOM length and gender and EOM was analysed. Any anatomical variation in the EOMs dissected would be noted.

Results: Mean (\pm SD) lengths in numerical order were: levator palpebrae superioris, 42.8 \pm 4.6mm, superior oblique, 39.2 \pm 4.5mm, medial rectus, 38.5 \pm 3.1mm, lateral rectus, 38.4 \pm 2.4mm, superior rectus, 38.2 \pm 4.1mm, inferior rectus, 37.2 \pm 2.4mm and inferior oblique, 22.5 \pm 4.4mm. Mean (\pm SD) cross-sectional diameters in numerical order were: medial rectus, 7.9 \pm 1.2mm, lateral rectus, 6.7 \pm 1.4mm, superior rectus, 6.5 \pm 1.3mm, inferior oblique, 6.5 \pm 0.9mm, inferior rectus, 6.2 \pm 0.9mm, levator palpebrae superioris, 6.0 \pm 1.1mm and superior oblique 4.3 \pm 1.1mm. There was no significant difference between left and right sides for length and cross-sectional diameter. There was also no association between age and length and age and cross-sectional diameter. There was no association between gender and length and gender and cross-sectional diameter.

Conclusion: This study presents normative measurements for EOM length and cross-sectional diameter. One anatomical variation was found: a thin muscle belly passing medially and originating from the same point as the LPS. This is estimated to occur in 8-15% of cases. Although no anatomical variations in the rectus muscles were observed this is likely due to their much lower frequency.

KEY WORDS: Extraocular Muscles, Length, Diameter, Variation, Levator Palpabrae Superioris.

Address for Correspondence: Edward Ridyard, 9 The Meadows, Rainhill, Prescot, L35 0PQ, UK.

E-Mail: edward-ridyard@doctors.org.uk

Access this Article online

Quick Response code



DOI: 10.16965/ijar.2015.164

Web site: International Journal of Anatomy and Research
ISSN 2321-4287
www.ijmhr.org/ijar.htm

Received: 23 Apr 2015

Accepted: 08 Jun 2015

Peer Review: 23 Apr 2015

Published (O): 02 Aug 2015

Revised: 12 May 2015

Published (P): 30 Sep 2015

INTRODUCTION

The extraocular muscles (EOM) are pivotal to the movement of the eye. There are 7 muscles within the orbit: 4 rectus muscles, 2 oblique muscles and the levator palpebrae superioris (LPS).

The rectus muscles arise from a common tendinous ring otherwise known as the annulus

of Zinn, a thickening of periosteum located at the apex of the orbital cavity. The muscles then project forward and insert into the 4 respective poles of the orbit and the muscles take the name of the pole into which they insert. The superior rectus (SR) inserts into the superior part of the sclera via a tendon approximately 5.5mm long.

The inferior rectus (IR) inserts into the inferior part of the sclera about 6.5mm from the limbus. The lateral rectus (LR) arises from the common tendinous ring but has a second small head which arises from the orbital surface of the greater wing of sphenoid bone. The LR inserts into the sclera by means of a tendon approximately 8.8mm long. The medial rectus (MR), the largest of the EOMs, inserts into the sclera via its tendon which is approximately 3.7mm long.

The two oblique muscles insert into the superior and inferior aspects of the eye and are named accordingly. The superior oblique (SO) arises from the body of the sphenoid and passes forward between the roof and medial wall of the orbital cavity. One portion of the IO arises from the floor of the orbit and another arises from the fascia covering the lacrimal sac. The muscle then follows the contour of the eyeball running inferiorly to the IR [1].

Anatomical variations in their anatomy have been described in previous studies:

1. A supernumerary rectus muscle between the IR and LR
2. A tripartite IR with a lateral muscle belly inserting into the IO
3. A medial muscle belly inserting medially into the IR [2]

Variations in the rectus and oblique muscles have been described in studies which date back to 1893 in which an "anomalous" rectus muscle was found arising with and medial to the LR[3]. The variations of the rectus muscles are thought to be remnants of the retractor bulbi, responsible for preventing the protusion of the eyeball in most mammals, amphibians and certain reptiles [2].

The LPS arises from the lesser wing of sphenoid bone, superoanterior to the optic canal[1,2]. From here it branches into a bilaminar aponeurosis and inserts into the superior tarsus as well as the skin of the superior eyelid [1].

In addition numerous anatomical variations of the LPS has been described:

1. A complete absence of the LPS
2. A unilateral accessory levator slip running parallel to the SO

3. A divided main belly of the LPS, producing either a bipartite or tripartite muscle which in turn forms a retrobulbar muscular arch
4. A slender accessory levator muscle slip from the medial and lateral margins of the LPS muscle
5. A bilateral lateral bipartite LPS [3,4]

There have been numerous studies aiming to quantify the size of the EOMs. These studies measured length, cross-sectional diameter and volumes of the EOMs [2,3,4]. There are numerous ways in which these measurements can be made. Dissection is the most straightforward method which involves exposing the orbit and physically measuring the EOMs. One of the first studies using dissection to measure the EOMs was by Volkmann in 1869[5]. Further dissection studies have since been done each providing a set of length measurements for the EOMs. Although dissection is undoubtedly an accurate method of measuring the EOMs in-situ it has the obvious drawback of being highly invasive and cannot be performed on a live subject. The development of imaging modalities such as CT and MRI provided a non-invasive and non-destructive means of measuring the EOMs. Most importantly of all they allowed measurements to be taken on live subjects. This also meant the sample sizes of the studies could be increased as live subjects were more readily available than cadavers. Between 1982 and 2010, 19 studies involving the EOMs were performed using CT [6]. However it was found that altering the window settings of the CT scanner, as well as changing the plane in which the scan was taken changed the results obtained for the EOMs. Between 1988 and 2007, 19 studies were performed with MRI to scan the orbit. However the strength of the magnet used in the scanner affected the accuracy of the results [7]. One study compared the results obtained for EOM length and cross-sectional diameter from CT and MRI and found similar results with the upper limit of normal values differing by less than 8.5% [8]. There have also been investigations visualising the orbit with ultrasound scanning (USS) [9]. Although USS was a more readily available and much cheaper alternative to CT or MRI, concerns were raised

over its accuracy. For this reason its use in quantifying EOM dimensions is limited and it is used in a clinical setting as a guide for gross EOM and orbital enlargement [10,11].

Many of the studies quantified the size of the EOMs in order to assess their disease status. Enlargement of the EOMs can be caused by a primary neoplasm, metastatic malignancy, trauma and infection as well as Grave's orbitopathy, this is the most common cause. Nugent imaged both normal subjects and patients with Grave's orbitopathy in order to observe the difference in EOM volume between the two groups. The study found all of the EOMs were enlarged in the Grave's orbitopathy group compared to the normal subjects. The biggest increase seen was in the SR of the Grave's orbitopathy group which was 63.4% larger than the SR of the normal subjects [12-14]. The aim of this study was to dissect the orbit and measure the length and cross-sectional diameter of normal EOMs to provide a set of normative measurements which is vital for determining when an EOM becomes pathological.

MATERIALS AND METHODS

Eighteen orbits from 9 formalin fixed cadavers (4 male and 5 female) were used with prior approval from the University of Manchester Anatomy Department. The mean age at death of the cadavers was 83 (range 70-95) and the cause of death ranged from metastatic disease to old age. The orbits were carefully inspected for any signs of trauma, deformities or significant volume loss. There was no history of pathology in any of the subjects which would affect the integrity of the extraocular muscles such as Grave's disease or tumours.

Both length and cross-sectional diameter measurements were taken with the aim of ranking the EOMs in numerical order for both sets of measurements. EOM length and cross-sectional diameters from left and right orbits were compared. The association between gender and EOM length and gender and EOM cross-sectional diameter was analysed. As well as this the correlation between age and EOM length and age and EOM cross-sectional diameter was also analysed. Finally any anatomical variation in the EOMs was documented.

The orbits were exposed to reveal the orbital contents and the EOMs dissected. Throughout the dissection tissue was handled in accordance to the Human Tissue Act, 2004.

Dissection: The cranial vault and cerebrum were removed to allow access to the orbital plate of the frontal bone with the orbit lying inferiorly.

The boundary between the frontal and nasal bone was cut using a necropsy saw. The lateral margin of the orbit formed by the frontal process of the zygomatic bone was then cut down to the level of the floor of the orbit. The temporalis muscle and fascia were removed using blunt dissection down to the zygomatic arch. The soft tissue of the face surrounding the orbit was removed using blunt dissection down to the level of the zygomatic arch. This level was traced anteriorly and the skin and underlying fascia surrounding the orbital opening were removed to expose the bone. A vertical cut was made using a necropsy saw into the wings of the sphenoid. A horizontal cut was then made through the frontal process of the zygomatic bone and was extended into the incision made into the sphenoid to connect the two cuts. The orbital contents were now exposed with good access to the lateral aspect of the orbit. The zygomatico-facial and temporal nerves were exposed on the superior aspect of the eye and the lacrimal gland on the superolateral aspect. This approach was adapted from Laurenson's original description in 1965 [15].

Dissection of the extraocular muscles: The approach used meant the first muscles exposed were the LPS and SR. The eyelids and the superior (after the point of insertion of the LPS) and inferior tarsal plates were removed prior to EOM dissection to allow the insertion points of the EOMs into the sclera to be best visible.

Measuring the EOMs: The length of each extraocular muscle was recorded using a digital caliper, Duratool 150mm (resolution 0.1mm and accuracy ± 0.2 mm). The halfway point of the muscle was calculated and logged on the caliper. The length was then measured on the muscle and the cross-sectional diameter of the muscle measured at this point to the nearest 0.1mm. This was done for all the 18 samples with a mean diameter taken for each EOM.

To ensure consistency the same digital caliper was used to take the measurements and the same investigator took three recordings of the length and cross-sectional diameters on three separate occasions.

Statistical analysis of the measurements: The data was analysed using SPSS, version 16. The data was tested for normality using the Kolmogorov-Smirnov test. For normally distributed data left and right variation in length and cross-sectional diameter were tested for using the unpaired t-test. Age and length as well as age and cross-sectional diameter correlation were tested for using the Pearson correlation coefficient. For normally distributed data the association between gender and length and gender and cross-sectional diameter were tested for using ANOVA.

For non-parametric data the Kruskal-Wallis test was used to analyse variation between left and right length and cross-sectional diameter. This was also used for gender variation in length and cross-sectional diameter. The Spearman rank correlation coefficient was used to analyse age and length as well as age and cross-sectional diameter variation for non-parametric data.

RESULTS

Lengths of the extraocular muscles: Lengths for all of the EOMs were normally distributed. The LPS was the longest of all the EOMs with a mean length of 47.8 ± 4.6 mm and the longest LPS measured was 50.7 mm. The LR was the largest of the rectus muscles with a mean length of 38.4 ± 3.1 mm. This was followed in numerical order by the MR, SR and then the IR with a mean length of 37.2 ± 2.4 mm. The IO was the shortest muscle with a mean length of 22.5 ± 4.4 mm.

Table 1: Summary of mean length (mm), standard deviation (SD) and range for each of EOMs arranged in numerical order from highest to lowest.

Length (mm)			
Muscle	Mean	SD	Range
LPS	42.8	4.6	10.7
SO	39.2	4.5	10.5
MR	38.5	3.1	16.9
LR	38.4	2.4	16.3
SR	38.2	4.1	8.8
IR	37.2	2.4	16.9
IO	22.5	4.4	15.1

Table 2: Summary of cross-sectional diameters (mm) for each EOM arranged in numerical order from highest to lowest.

Cross-sectional diameter (mm)			
Muscle	Mean	SD	Range
MR	7.9	1.2	4.3
LR	6.7	1.4	5.7
SR	6.5	1.3	4.3
IO	6.5	0.9	3.5
IR	6.2	0.9	3.2
LPS	6	1.1	3.4
SO	4.3	1.1	4.4

Table 3: Comparison of EOM lengths (mm) obtained from this study and those from Lang et al with and without the tendon length included [16], - indicates no measurement was obtained.

Muscle	EOM Lengths from this	Lang et al- Muscle belly	Lang et al- Muscle belly w/ tendon
LPS	42.8	41.2	-
SO	39.2	-	-
MR	38.5	37.7	42.4
LR	38.4	36.3	43.5
SR	38.2	37.3	41.6
IR	37.2	37.7	44.9
IO	22.5	31.5	-

Table 4: Summary of ranges for the EOMs for this study and the study by Ozgen and Aydingoz, - indicates no measurement was obtained [9].

Muscle	Range for this study (mm)	Range for Ozgen and Aydingoz (mm)
MR	4.3	1.7
LR	5.7	2.2
SR	4.3	2.5
IO	3.5	-
IR	3.2	2.3
LPS	3.4	2.5
SO	4.4	-

The range of lengths was greatest for the LPS and SR, both with a range of 16.9 mm. The IR had the smallest range of 8.8 mm. The largest muscle measured overall was the SR with a length of 50.9 mm and the smallest was the IO with a length of 15.2 mm.

Cross-sectional diameters of the extraocular muscles: Cross-sectional diameters for all of the EOMs were normally distributed apart from the LR (KS $p < 0.05$). The MR had the greatest cross-sectional diameter with a length of 7.9 ± 1.2 mm.

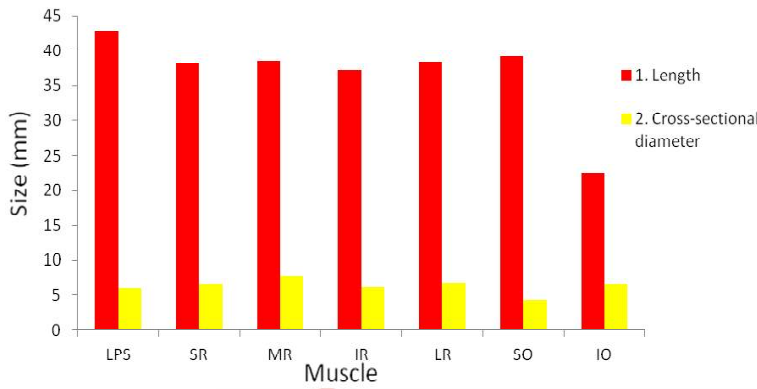


Fig. 1: A graph to show the mean length (mm) and cross-sectional diameter (mm) for each EOM.

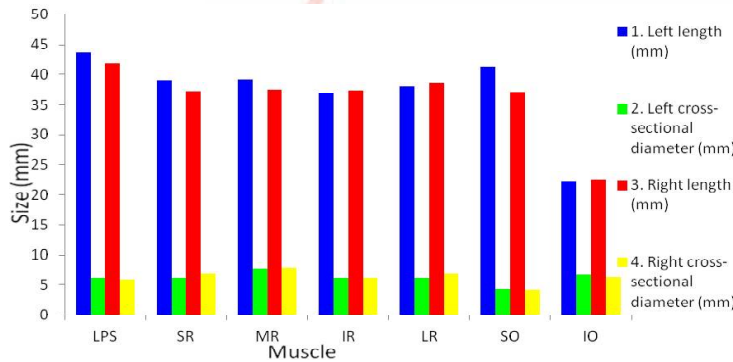


Fig. 2: A graph to show the mean length (mm) and cross-sectional diameter (mm) for the left and right EOMs.

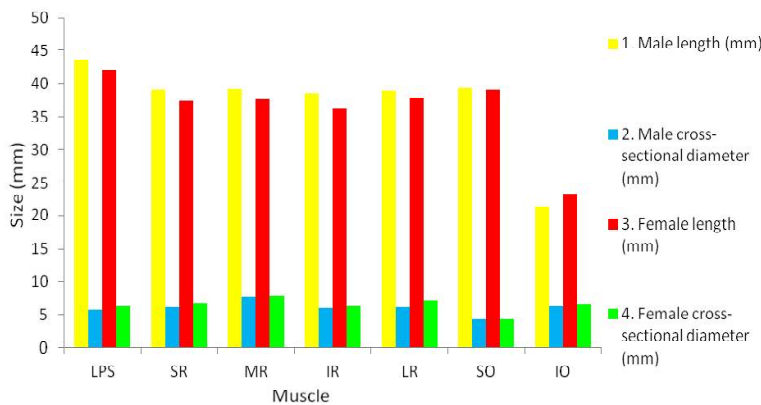


Fig. 3: A graph to show the mean length (mm) and cross-sectional diameter (mm) for male and female extraocular muscles.

This was followed in numerical order by the LR, SR, IO, IR, LPS and finally the SO with a cross-sectional diameter of 4.3 ± 1.1 mm. The LR had the largest cross-sectional diameter measurement of 10.8 mm, whilst the SO had the smallest with 2.2 mm. The range of the cross-sectional diameters was greatest for the LR with a range of 5.7 mm. The IR had the smallest with a range of 3.2 mm.

Figure 3: A graph to show the mean length (mm) and cross-sectional diameter (mm) for each extraocular muscle, with standard deviation (SD)

Variation in length between left and right extraocular muscles: There was no significant difference observed for length between the left and right EOMs ($p > 0.05$).

Variation in cross-sectional diameter between left and right extraocular muscles: There was no significant difference observed for cross-

sectional diameter between the left and right EOMs ($p > 0.05$).

Age and variation in extraocular muscle length and cross-sectional diameter: The age range of the cadavers was 70-95 at death. There was no significant correlation found between age and EOM length ($p > 0.05$). There was also no significant correlation found between age and the cross-sectional of EOMs ($p > 0.05$).

Association between gender and variation in extraocular muscle length and cross-sectional diameter: There was no significant association found between gender and length of the EOMs ($p > 0.05$). There was also no significant association found between gender and cross-sectional area ($p > 0.05$).

Anatomical variation in the extraocular muscles: An interesting anatomical variation was found in the LPS of the left orbit of one of

the subjects. A small distinct muscle branched off the LPS and moved medially to insert into the orbital fat at roughly the halfway point between the LPS-SR complex and the MR. It measured 32.8mm in length and had a cross-sectional diameter of 1.4mm.

DISCUSSION

The aim of this study was to dissect the EOMs and analyse their length and cross-sectional diameter. The variation between left and right side, age and gender was also analysed.

Variation in extraocular muscle length: All muscle lengths in the 18 orbits dissected were measured. The LPS was found to be the longest with the following order for the remaining EOMs: SO>MR>LR>SR>IR>IO. This is only partially supported by a study by Lang et al who found the following order: LPS>MR>SR>IR>LR>IO, although the SO was not measured in this study. Furthermore Lang et al measured the muscle belly and the tendon length separately whereas this study combined the muscle belly and tendon lengths in one measurement from the origin to insertion of each muscle. The combined length of the muscle belly and tendon from Lang et al ranks the EOMs as follows: IR>LR>MR>LPS>IO. Not only is the order different from this study but the values obtained for the EOM lengths are different too. **Table3** compares the results obtained from this study compared to the results obtained from the Lang et al study [16].

The Lang et al was a better powered study with 59 compared to the 18 orbits dissected in this study. It could be that the EOMs measured in this study were on the whole smaller than those of Lang et al and this could be due to any number of factors such as race, age or gender [16].

Although in this study the LPS had the highest average, the largest single measurement was for the SR with a measurement of 50.9mm. This was for a male with an age of 75 at death. Lang et al's maximum measurement for the SR muscle belly was 45.0mm and the maximum value for the tendon was 6.0mm [16]. If one combines these two measurements this would provide a combined length of 51.0mm. Thus it has been described previously that the SR could reach this length.

The IO was found to have an average length of 22.5mm in this study. This was significantly lower than the length of 31.5mm described by Lang et al for the IO [16]. However Wolff disagrees further giving an even larger average length of 37.0mm for the IO [17]. Therefore it would appear there is no consistent measurement for the cross-sectional diameter of the IO. Furthermore the range of lengths for the IO in this study was great, with the largest measuring 30.5mm and smallest measuring 15.2mm. Given this great disparity between the highest and lowest values and the lack of concordance between studies suggests the IO's length is very variable between individuals.

Variation in extraocular muscle cross-sectional diameter: The MR was found to have the largest cross-sectional diameter of 7.9mm, the remaining order of the EOMs from highest to lowest was LR>SR>IO>IR>LPS>SO. However Ozgen and Ariyurek did a similar study and found a different order: IR>SG>MR>LR>SO. The order is different to the order of this study but there is agreement that the SO has the smallest cross-sectional diameter. Furthermore the values obtained by Ozgen and Ariyurek are different to this study. **Table4** compares the results from this study and those from Ozgen and Ariyurek. The maximum value from this study was 7.9mm for the MR which is considerably larger than that of the maximum value of 4.8mm from the Ozgen and Ariyurek study [10].

Ozgen and Ariyurek chose to measure the cross-sectional diameter of the EOMs at their maximum point rather than at the halfway point between their origin and insertion. Therefore it is possible that the values obtained from this investigation were not the maximum values for the cross-sectional diameter as it is unlikely that the halfway point would correspond to the point of the EOM's maximum size in every instance. The MR in this study for example had the largest cross-sectional diameter but was the second smallest in the Ozgen and Ariyurek study [10]. The MR's muscle belly could be at its largest at the halfway point whereas the IR whose cross-sectional diameter was third smallest in this study but the largest in Ozgen and Ariyurek's [10] study could have a structure which sees its maximum muscle belly size either side of the

halfway point. Thus the order of the cross-sectional diameters for each EOM from this study may well have been different if the maximum cross-sectional diameter was taken.

There is agreement between Ozgen and Ariyurek and another study done by Ozgen and Aydingoz, this time investigating the cross-sectional diameters of the EOMs with MRI. The order of the cross-sectional diameters was the same and the values obtained were similar [9,10]. However unlike these two studies this investigation used cadaveric dissection rather than imaging a living subject. Although these two studies which imaged living subjects agree, it could be changes that occur in cadavers after death which affected the values obtained for cross-sectional diameter for this study. Conservation procedures such as refrigeration and embalming, which involves leaving the cadaver in formalin for an extended period may affect the structure and therefore size of the EOM's cross-sectional diameter [16].

Therefore if the same EOMs from this study were imaged with CT or MRI and their cross-sectional diameters measured with the subject living rather than as a cadaver it would be interesting to see whether the values obtained would be different.

One limitation of the study was the time at which the EOMs were measured as this could have affected the results obtained. In this study the EOMs were measured en-masse after all 18 orbits were dissected, in order to keep the results obtained consistent. However the orbits dissected first will be subject to accelerated dehydration compared to those with the orbit intact which were dissected towards the end. This accelerated dehydration could reduce the cross-sectional diameter of the EOMs. If one compares the range of results from this investigation with the study by Ozgen and Aydingoz who used MRI to image the EOMs and therefore accelerated dehydration was not a factor, it is larger. The biggest range of cross-sectional diameter measurements from this study was for the LR with a range of 5.7mm. In contrast the largest range from the Ozgen and Aydingoz study was 2.5mm for the SG [9]. If the EOMs were measured straight after dissection before accelerated dehydration became a factor the results could have been more congruous and

the range of the results reduced.

Association between gender and variation in extraocular muscle length and cross-sectional diameter:

No significant association was found between gender and length and gender and cross-sectional diameter. This is something which is supported by the Shen and Fong study [19]. However the study by Ozgen and Ariyurek and the study by Ozgen and Aydingoz found that males had significantly larger EOM lengths and cross-sectional diameters[9,10]. Although these studies appear to disagree with this investigation it is interesting to note that the interzygomatic line which corresponds to head size was also measured in these two studies. It was found that the interzygomatic line corresponded to the length and cross-sectional diameter of the EOMs. Most interesting of all was the ratio of the length of the interzygomatic line and the cross-sectional diameter of the EOMs was not statistically significant between male and female. In these studies the length of the interzygomatic line was larger for males than for females and this accounted for the increase in cross-sectional diameter seen between the genders [9,10]. In this investigation it could well be that the head size between male and female was similar and therefore the interzygomatic line was not significantly different and therefore there was no significant difference found between the male and female cross-sectional diameters.

Age and variation in extraocular muscle length and cross-sectional diameter:

No correlation was found between age and EOM length and age and cross-sectional diameter in this study. This is something which is supported by the Shen and Fong study [19]. Again however the study by Ozgen and Aydingoz and the study by Ozgen and Ariyurek found an increase in cross-sectional diameter of the LR and IR with age. The age range in these two studies was 16-77 and 18-70 respectively [9,10]. These two age ranges could be considered to represent the entire age range of the adult population. This is interesting because the study by Shen and Fong had an age range of 20-60 [19] which could be argued to neglect the last two decades of average life expectancy. This investigation had an age range of 70-95 and therefore does not

represent the younger population. Thus it could well be that the main changes in cross-sectional diameter described by the two Ozgen et al studies occur at an age which has already been reached by the subjects in our study and yet to be reached by the subjects in the Shen and Fong study. This would explain there being no statistically significant differences for cross-sectional diameter and age for any of the EOMs. It would be intriguing to see whether if the age range was increased in this investigation and indeed the Shen and Fong study, if any significant differences for age and cross-sectional diameter of the EOMs would be observed.

Anatomical variation in the extraocular muscles: All EOMs were present within the 18 orbits dissected. This is supported by other studies which found absent EOMs to be rare, except in children with ocular mobility disorders. As well as this all of the rectus and oblique muscles had the expected origins and insertions and there was no anatomical variation. There was however a variation seen in the left LPS in one of the subjects. A thin muscular slip passed medially from and shared its origin with the LPS (**Figure1**). An accessory muscular slip is estimated to occur in 8-15% of cases [4,5].

Yalin et al did a similar study to this investigation, dissecting 60 orbits looking specifically for variation in the LPS. Three anatomical variations of the LPS were found [20]. Interestingly one of the variations Yalcin et al described fitted the description of the variation found for the LPS in this study: a medial origin and trajectory, with the muscle losing its muscular character after a short distance and inserting into the intermuscular fascia at some point between the LPS-SR complex and the MR [20]. This variation has also been described in other studies [3,4] and consequently is now referred to as the levator trochleae due its tendinous insertion into the trochlea.

In terms of consequences this variation would have had the subject when they were alive, LPS variation is thought to be involved in the aetiology of blepharoptosis which involves the drooping of the upper eyelid of the affected eye. One study provided evidence that the cause of blepharoptosis is LPS muscle dysgenesis rather than LPS dystrophy [21]. Muscle dystrophy would

have lead to a weakened LPS muscle and consequent drooping of the upper eyelid but muscle dysgenesis causes an abnormal structure of the LPS which in turn affects the integrity of its aponeurosis. Therefore its action of keeping the upper eyelid retracted is impeded leading to blepharoptosis.

Although no anatomical variations of the rectus muscles were found in our study this could be due to the much lower frequency of rectus and oblique muscle anatomical variation². Variations in the rectus and oblique muscles have been described in studies which date back to 1893 in which an "anomalous" rectus muscle was found arising with and medial to the LR. The variations of the rectus muscles are thought to be remnants of the retractor bulbi, responsible for preventing the protrusion of the eyeball in amphibians, certain reptiles and most mammals [1]. Furthermore it is arguable that the rectus and oblique muscles fulfil a much more important role than the LPS, as between them they are involved in all the movement of the eyeball, whereas the LPS has the much less important role of keeping the eyelid fully retracted. A defect in a rectus or oblique muscle causing dysfunction would have had much more severe consequences for the survival of a person who for example would lose all lateral movement of the eye if the LR function was lost, therefore losing peripheral vision and being much more susceptible to attack in the wild. Therefore it is possible that the proper anatomical form of the rectus and oblique muscles allowing their normal function has been better conserved than that of the LPS.

CONCLUSION

Dissection provides a method to accurately measure the EOMs and this study has provided normative measurements for both length and cross-sectional for all of the EOMs. The numerical order of the EOMs for length and cross-sectional diameter from this study differ slightly from the order of other studies, as well as the values obtained. The reasons behind this discrepancy have been discussed.

In agreement with previous literature there is no difference between the left and right sides of normal healthy orbits. Furthermore this study

concludes that there is no correlation between age and EOM length and cross-sectional diameter and no association between gender and EOM length and cross-sectional diameter. Some but not all of the studies agree with this observation. The possible reasons for this disagreement have been discussed. One anatomical variation was found for the LPS and this is the most commonly observed anatomical variation of the EOMs.

Source of Funding: This study was generously supported by a grant from the JHG Holt Fund.

Conflicts of Interests: None

REFERENCES

- [1]. Snell RS, Lemp MA. Clinical Anatomy of the Eye. 2nd ed. USA: Blackwell Science. 1998; 231-271.
- [2]. Von Lüdinghausen M, Miura M, Würzler N. Variations and anomalies of the human orbital muscles. *Surg Radiol Anat.* 1999; 21:69-76.
- [3]. Nussbaum M. Vergleichend-anatomische Beiträge zur Kenntnis der Augenmuskeln. *Anat Anz.* 1893; 8:208-210.
- [4]. Macalister A. Additional observations on muscular anomalies in human anatomy (third series), with a catalogue of the principal muscular variations hitherto published. *Trans R Irish Acad Sci.* 1875; 25:1-134.
- [5]. Bergman RA, Thompson SA, Afifi AK. Catalog of Human Variation. Baltimore, MD: Urban & Schwarzenberg. 1984.
- [6]. Plock J, Contaldo C, Von Lüdinghausen M. Levator palpebrae superioris muscle in human fetuses: anatomical findings and their clinical relevance. *Clin Anat.* 2005; 18:473-80.
- [7]. Volkmann A W. Über die mechanika der augenmuskeln. *Ber. Verh. Sächs. Acad. Wiss.* 1869; 21:28-69.
- [8]. Ridyard EJ. Literature review- Extraocular muscles: imaging, variation and clinical applications of their imaging. University of Manchester. 2011; 1:6-13.
- [9]. Ozgen A, Aydingöz U. Normative measurements of orbital structures using MRI. *J Comput Assist Tomogr.* 2000; 24:493-496.
- [10]. Ozgen A, Ariyurek M. Normative measurements of orbital structures using CT. *AJR Am J Roentgenol.* 1998; 170:1093-1096.
- [11]. Pierro, L. Zaganelli, E. Tavola, A. Muraglia, M. Extraocular muscle size comparison between normal and myopic eyes using standardized A scan echography. *Ophthalmologica.* 1998; 1:22-24.
- [12]. Demer JL, Kerman BM. Comparison of standardized echography with magnetic resonance imaging to measure extraocular muscle size. *Am J Ophthalmol* 1994; 118:351-361.
- [13]. McNutt LC, Kaefring SL, Ossoinig KC. Echographic measurement of extraocular muscles. In: White D, Brown RE, eds. *Ultrasound in medicine.* New York: Plenum Press. 1977; 927-932.
- [14]. Nugent R A, Belkin RI, Neigel JM, Rootman J, Robertson WD, Spinelli J, Graeb DA. Graves orbitopathy: correlation of CT and clinical findings *Radiology.* 1990; 177:675-682.
- [15]. Laurensen RD. Dissection of the orbit. *Anat Rec.* 1965; 152:537-539.
- [16]. Lang J, Horn T, von den Eichen U. External eye muscles and their attachment zones. *Gegenbaurs Morphol Jahrb.* 1980; 126:817-840.
- [17]. Bron J, Tripathi RC, Tripathi BJ. *Wolff's Anatomy of the eye and the orbit.* 8th ed. UK: Chapman & Hall London. 1997: 107-177.
- [18]. Paik DJ, Shin SY. An anatomical study of the inferior oblique muscle: The embalmed cadaver vs the fresh cadaver. *Am J Ophthalmol.* 2009; 147:544-549.
- [19]. Shen S, Fong KS, Wong HB, Looi A, Chan LL, Rootman J, Seah LL. Normative measurements of the Chinese extraocular musculature by high-field magnetic resonance imaging. *Invest Ophthalmol Vis Sci.* 2010; 51:631-636.
- [20]. Yalcin B, Hurmeric V, Loukas M, Tubbs RS, Ozan H. Accessory levator muscle slips of the levator palpebrae superioris muscle. *Clin Experiment Ophthalmol.* 2009; 37:407-411.
- [21]. Baldwin HC, Manners RM. Congenital blepharoptosis: a literature review of the histology of levator palpebrae superioris muscle. *Ophthal Plast Reconstr Surg.* 2002; 18: 301-307.

How to cite this article:

Edward Ridyard. EXTRAOCULAR MUSCLES: VARIATION IN THEIR ANATOMY, LENGTH AND CROSS-SECTIONAL DIAMETER. *Int J Anat Res* 2015;3(3):1198-1206. **DOI:** 10.16965/ijar.2015.164